Agroecozones of the United States Northern Plains

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ABSTRACT

Ecoclimatic zones that integrate soil climate and length of growing period for agronomic systems were determined within (55) Major Land Resource Areas (MLRAs) by integrating the Normalized Difference Vegetative Index (NDVI), soil climate, growing degree day, and root zone available water capacity for STATSGO (State Soil Geographic Data Base) delineations. A quantitative, multivariate regionalization model was tested and applied for agroecozone regionalization in Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, and Kansas, USA. The model aggregated small agroecological units into regions that subdivide expert determined MLRA regions using a hierarchical clustering procedure. Each MLRA region was developed using STATSGO coverages by state and regional USDA-NRCS scientists in an Arcview GIS decision support system called MARTHAíS (MLRA Revision Through the Aggregation of STATSGO). Agroecological parameters for each unit were merged based on similarities of these features and their neighborhood derived from GIS topological files. Agroecological parameters considered were: root zone available water capacity; 1961-1990 averages for growing degree days base 50°F and modified Newhall simulations of annual moisture balance that were terrain modeled using 3-arc second USGS DEMS and linear regression; Advanced Very High Resolution Radiometer (AVHRR) NDVI as (8) bi-weekly averages for the 1991 growing season; and STATSGO polygon geography. The resulting agroecozones, also known as Common Resource Areas (CRAs), were evaluated by USDA-NRCS scientists for stratifying Field Office Technical Guide (FOTG) Best Management Practice (BMP) templates within the 7 state Northern Plains Administrative Region (Figure 1).

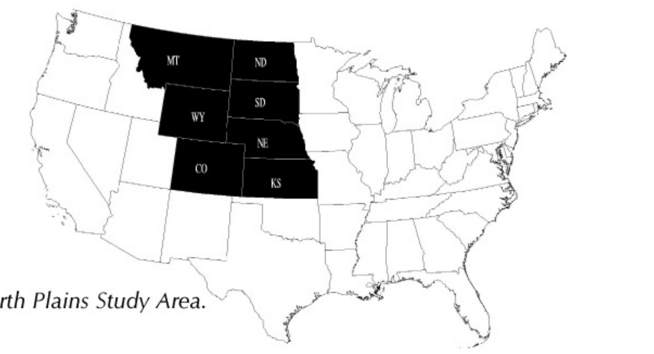

Figure 1. North Plains Study Area.

INTRODUCTION

Local land resource management and environmental monitoring require a geographical framework for making policies and management strategies on regional rather than a site-by-site basis (Bailey et al, 1985). The Land Resource Regions (LRRs) and the Major Land Resource Area (MLRAs) are part of the USDA-Natural Resources Conservation Service geographical framework presently in use. This framework was published by Austin in 1972 and later revised in 1981 (USDA, 1981). This framework provides a geographical basis for making national and regional-level management decisions about agricultural concern, resource information, and the organization of conservation programs.

The traditional LRR/MLRA framework could be considered a framework of Agroecozones according to the following definitions (Table 1). An **agroecosystem** is an interactive group of biotic and abiotic components, some of which are under human control that form a unified whole (ecosystem) for the purpose of producing food and fiber (Elliot and Cole, 1989). An **agroecozone** is a major climate zone, in terms of growing period which is suitable for a spectrum of crops and that is segmented by land form and kinds of soil that act to modify the effectiveness of climate and length of growing period for acceptably productive, economically viable, and sustainable agricultural production systems (Follett et al, 1996). Follett et al (1996) also believed that the technology and knowledge base exists to develop a system for characterizing and analyzing the true ìdynamicî nature of agroecosystems at the regional and national levels. They also recognized that a ìtransdisciplinary systems approach would provide more power and flexibility, and could be tailored to meet a wide variety of needsî.

Table 1. USDA-Natural Resources Agroecozone Hierarchical Framework.

LAND RESOURCE REGIONS (LRR)
(1:7,500,000)
Parameters: Growing Regions Suitable for a Group of Crops and Cropping Systems; Broad Soil Productivity and Major Land Resource Areas

MAJOR LAND RESOURCE AREAS (MLRA)
(1:3,500,000)
Parameters: Soils, Physiography (elevation and topography), Land Use/Land Cover, Climate, Hydrology, Potential Natural Vegetation

Common Resource Areas (CRA)
(formerly Land Resource Units)
(1:1,000,000)
Parameters: Climatic Characteristics (Moisture Deficit, Growing Degree-Days, Biological Windows), and Soil Productivity/Management Groups

General Soil Maps (STATSGO)
(1:250,000)
Parameters: Land form, Parent Materials, Local Soil Climate

Most of the previous ecological or environmental region frameworks were developed using expert evaluation and qualitative analysis of *in situ* data. Such methods of manual region delineations are time-consuming and laborious processes. When multiple information layers were needed to define regions, the judgement of boundary locations become very difficult and resulted in subjective and possibly uncertain decisions.

The existing USDA-NRCS framework of MLRAs is being critically evaluated using new information and technologies, often in the context of USEPA and US Forest Service ecological regions. This research supports this evaluation by capturing the expert knowledge of NRCS scientists through desktop Geographic Information Systems (GIS) to determine MLRAs and combining this knowledge with a regionalization model which evaluates environmental parameters simultaneously in order to derive the Common Resource Areas within the expertly determined MLRAs. The ecological units (Common Resource Areas) defined by this research are hierarchically organized and exclusive from one another.

The regionalization model uses spatial environmental information including remote sensing derived AVHRR-NDVI biweekly composites, climate, soils, and topographic data to determine CRAs for the United States Northern Plains Region.

METHODOLOGY

MARTHAíS

MLRA Revision THrough the Aggregation of STATSGO (MARTHAíS) is a spatial decision support system (SDSS) developed by Natural Resources Conservation Service (NRCS) in conjunction with the Consortium for International Earth Science Information Network (CIESIN) for the purpose of revising Major Land Resource Areas (MLRA) regions using State Soil Geographic Data Base (STATSGO) polygon data. In 1996, NRCS began to revise the 1984 version of MLRAs (1:7,500,000 scale) through the aggregation of STATSGO polygon delineation's (1:250,000 scale). The main benefit of this effort is the logical linkage between two formerly separate and independently created data sets, MLRA vs. STATSGO. See Diagram 1.

Using the expert knowledge of NRCS soil scientists with the larger scale of the STATSGO data, a more precise and accurate national MLRA approximation is generated. Using STATSGO data, soil scientists may examine the landscape in terms of soil complexes, surficial and bedrock geology, land use/land cover, climate data, topography, and other reference data in a GIS (Figure 2). Working with NRCS personnel, the Active Response Geographic Information System (AR/GIS) team of CIESIN created a powerful SDSS for the soil scientist using ArcView GIS and AR/GIS customized functionality. This functionality facilitates iterative reclassification of MLRA concepts according to STATSGO polygons as well as identifying data errors and misclassifications.

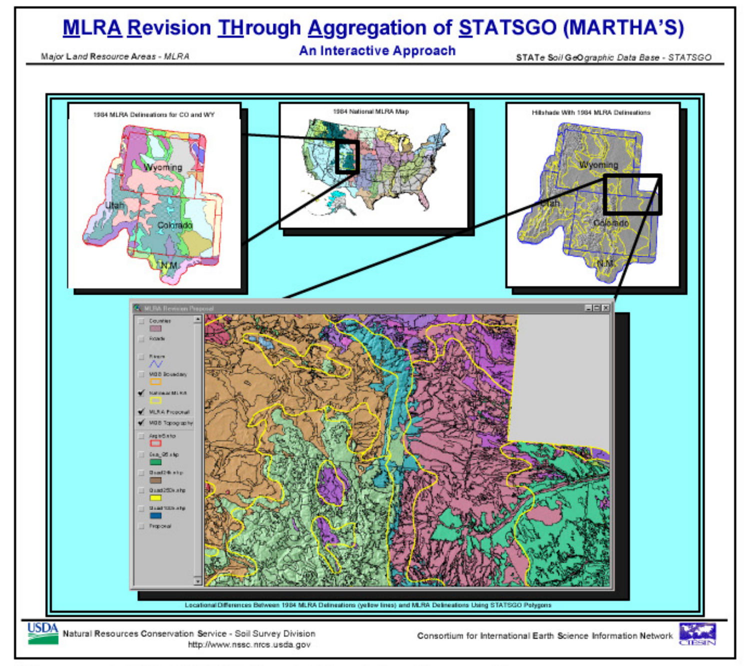

Diagram 1. MARTHAíS Spatial Decision Support System

Figure 2. NRCS Scientist use MARTHAíS Arcview GIS application to revise MLRA regions.

Each reclassification set can be traced through the use of rationale files created by the soil scientist and are attached to each reclassified polygon record. The system expedites refinement of MLRA delineation using STATSGO polygons to generate a new MLRA map data set that contains new, more precise and accurate delineation's that capture soil scientist expertise, knowledge, and spatial reasoning The system also eliminates the need for re-digitizing new MLRA lines (See examples in Figures 3 and 4).

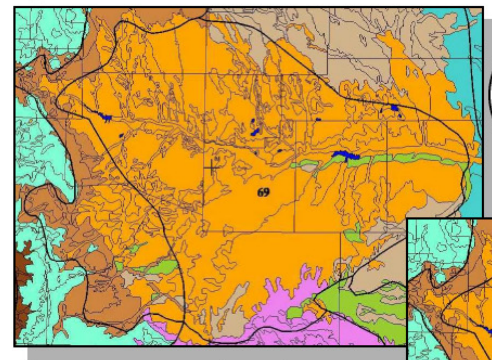

Figure 3. STATSGO derived MLRA region before MARTHAíS edit.

MLRA 69 - Upper Arkansas Valley Rolling Plains, located in southeast Colorado, USA (shown in orange).

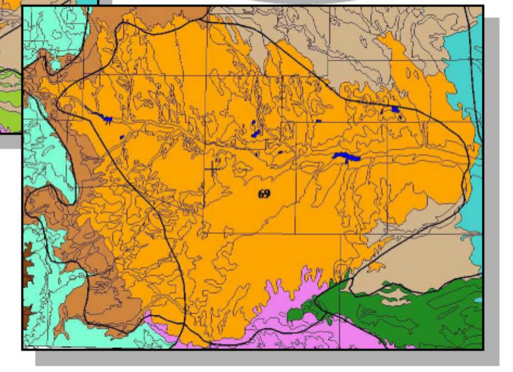

Figure 4. STATSGO derived MLRA region after MARTHAíS edit.

DATA SOURCES

State Soil Geographic Data Base (STATSGO):

Compared with MLRA, USEPA, or USFS ecoregion map units, this soil data set is mapped at a much finer resolution and with much smaller delineations or polygons. STATSGO polygons are defined as the ecological unit at the lowest level in the hierarchy. An assumption is made that the ìgeneral soil map unitî concept implies a relative homogeneity of micro-climate, micro-landform, and vegetation pattern within each soil map unit polygon. The use of STATSGO in the model reduces the data volume of remotely sensed imagery summarizing ecological parameters (e.g. Vegetation Indices) within the map units. In addition, the polygon neighborhood relationships derived from these vector maps are useful in maintaining contiguity of regions during the modeling process. There are 16,178 STATSGO polygons in the Northern Plains study area. This study used a final modified STATSGO coverage that contained 14,990 polygons after the removal of 1,188 water polygons. There are portions of 55 MLRA categories in the Northern Plains study area.

NDVI (Greenness Index):

Vegetation indices derived from remotely sensed data have been found to be sensitive to the presence and condition of green vegetation. The NDVI is one of the commonly used vegetation indices (Goward et al., 1985). Presently, the most appropriate remote sensing data that are available for characterizing the vegetation cover of a large study area are the bi-weekly NDVI composites compiled by the USGS EROS Data Center. These data are derived from the NOAA-AVHRR satellites that acquire data at a nominal spatial resolution of 1 x 1-km. For the purpose of this study, one NDVI bi-weekly composite from each month of the growing season (March ñ October) in 1991 was selected as input to the model for vegetation discrimination. The selection of composites resulted in a representative and efficient (less redundant) data set for the regionalization model. NDVI = (Near Infrared ñ red) / (Near Infrared + red). Figure 5 (A) ñ (H) illustrates selected bi-weekly composites as averaged within modified STATSGO polygons.

Climate

The study used terrain modeled climate data prepared for the Northern Plains State of the Land (USDA-NRCS, 1996). This work used a terrain modeling approach in conjunction with the NSM (Van Wambeke et al, 1992) to spatially project climatic parameters, such as growing-degree days and annual moisture balance. The transfer of climatic parameters to terrain data (1:250,000 scale USGS digital elevation models ñ DEMs) followed a methodology similar to that of Ollinger et al. (1995). Regression equations were derived from a population of 875 weather stations with 1961 to 1990 normals in the Northern Plains study area. The regression equations were based on five landscape parameters including easting (longitude), northing (latitude), elevation, slope, and aspect. Figure 5 (I) illustrates the growing degree days (base 50 degrees F) and (J) illustrates annual moisture balance as summarized by modified STATSGO polygons.

TOPOGRAPHY

Because the climate data include topographic parameters (i.e., elevation, slope, and aspect), no further input on topography was required.

STATSGO AVAILABLE WATER CAPACITY IN EFFECTIVE ROOT ZONE

The root zone available water capacity (AWC) for was calculated and weighted by component percentage for each soil component of each STATSGO map unit within the Northern Plains study area (USDA, Soil Survey Staff, 1999). Figure 5 (K) illustrates the weighted AWC values for modified STATSGO polygons within the study area.

REGION PARTITION

Generalizing parameter values within base map unit (i.e. modified STATSGO polygons) was the first step in the modeling process. For each data layer, the data values were averaged within the STATSGO map units. Examples of the averaged parameter values for each of (11) parameters are shown in Figure 5.

The model generates regions by aggregating the STATSGO polygons for each variable through a hierarchical clustering procedure. Two criteria are used to control cluster merges:

1. Similarity between map units or cluster, which involves computing the similarity index (SI).
2. Establishing neighborhood relationships, whereby, two units are assigned to one cluster only if they are spatially adjacent to each other.

The aggregating process iteratively searches for the pair of polygons with the smallest SI, and merges them into one cluster if they are spatially connected. Figure 6 is a schematic diagram that illustrates the process that is implemented by the algorithm.

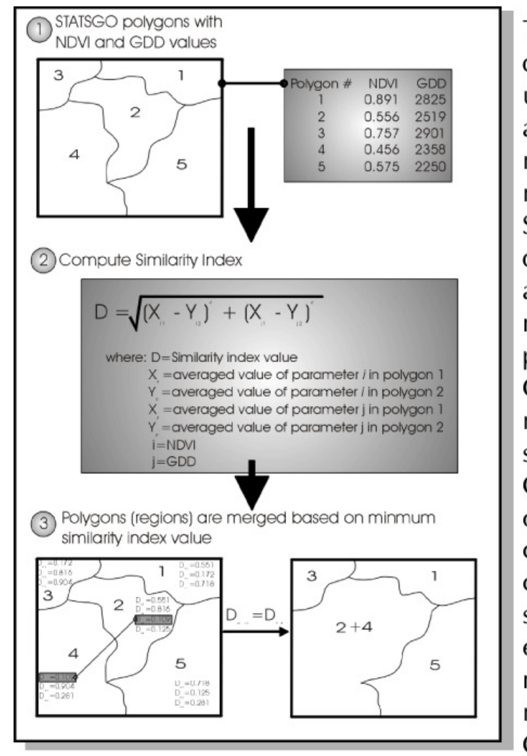

Figure 6. Conceptual diagram illustrating the STATSGO polygon aggregation process based on lowest Similarity Index (SI) value.

Two strategies were used to develop the draft CRAs. The first used standard Similarity Index (SI) and Cluster Size (CS) of .3 and 5, respectively for each MLRA region. The second increased the SI to .5 and varied the CS until the desired number of CRAs was achieved. Cluster Size (CS) is the minimum number of STATSGO polygons required to create a new CRA within an individual MLRA region. The Northern Plains NRCS scientists identified a target of 3 CRA subdivisions, however to optimize the expert reviewers choices, some MLRA regions were clustered for 4 to 10 possible CRA subdivisions. The use of local experts (NRCS scientists) will be necessary to consolidate MLRA regions into the desired 3 draft CRAs per MLRA region.

RESULTS

Eighty-one (81) MLRA regions were created from a dissolve of the MARTHAíS edited STATSGO coverage as shown in Figure 5 (L). Eleven (11) MLRA regions have multiple or repeating polygons.

Six (6) MLRA regions were not processed due to their very small size. These MLRA regions were mostly located on the outer boundary of the Northern Plains Conservation Region. These MLRA regions included: 13, 35, 37, 47III, 48BII, 60BIII, and 116A.

MLRA 69, known as the **Upper Arkansas Valley Rolling Plains** located in southeast Colorado is chosen to serve as a single example representive of the 187 proposals prepared in this study.

Figure 7 illustrates the after MARTHAíS STATSGO based MLRA 69 region with the SI = .3 and CS = 5 Common Resource Area proposal.

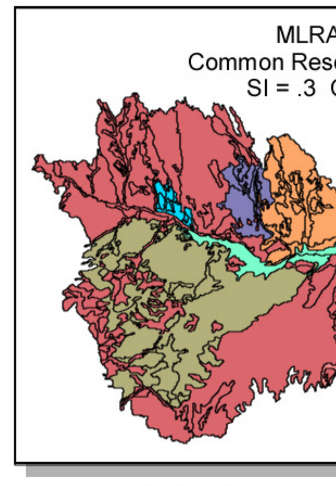

Figure 7. MLRA 69 CRA proposal SI=.3 and C5=5 yielded 9 CRAs.

Figure 8 illustrates the after MARTHAíS STATSGO based MLRA 69 region with the SI = .5 and the CS = 4 Common Resource Area proposal. The 1981 generalized version of MLRA 69 was reported to have an area = 34,000 km^2 or 13,130 mi^2 (USDA, 1981). The MARTHAíS STATSGO base for MLRA 69 has an area of 33,192 km^2 or 12,817 mi^2, which represents 2.4 percent reduction is size compared to the 1981 MLRA 69.

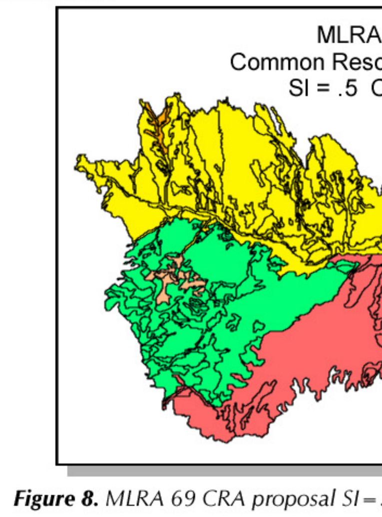

Figure 8. MLRA 69 CRA proposal SI=.5 and CS=4 yielded 5 CRAs.

At least two CRA proposal were prepared for each of the MLRA regions in the study area, yielding 187 CRA proposals. Each proposal was printed onto a color 8.5îx11î map and delivered to the Northern Plains scientists for review, along with large format color maps (24îx24î, 1:3,500,000 scale) illustrating the (11) input parameters featured in Figure 5. These data were also shared via CD-ROM to facilitate printing at regional offices for field level review. The review process is presently ongoing.

Figure 5. Eleven input parameters used by the Regionalization Model (A) - (K) and MARTHAíS modified MLRA regions (L).

(A) NDVI March 1991 (B) NDVI April 1991 (C) NDVI May 1991 (D) NDVI June 1991 (E) NDVI July 1991 (F) NDVI August 1991 (G) NDVI September 1991 (H) NDVI October 1991 (I) Growing Degree Days 1961-90 Normals (J) Annual Moisture Balance 1961-90 Normals (K) Available Water Capacity in Effective Rooting Zone (L) MARTHAíS Revised MLRA Regions

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